Dataset for multi-model comparison and ensemble simulations of canola growth and yield across global sites

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Abstract: This paper describes the dataset that was used to test the reliability of eight crop models in simulating growth and yield of canola in response to sowing dates, nitrogen inputs and climate variability across five countries. The dataset includes four spring cultivars and three winter cultivars across six sites, which represents a diverse range of canola production areas around the world. Model calibration and validation were conducted in the framework of the Agricultural Model Intercomparison and Improvement Project for canola (AgMIP-Canola). Field experimental datasets include site characterization, soil profile characterization, initial soil conditions (soil water and mineral nitrogen contents), in-season and end-season crop measurements (phenology, LAI, biomass, and nitrogen content in leaves, stems and pods, some with seed oil content), and daily weather data. Simulation datasets include the simulation results generated by ten individual model frameworks (eight crop models, APSIM and DSSAT respectively by two groups) for the experimental periods, and scenario simulations using 30 years historical weather data (1981 – 2010) together with a full multi-factorial combinations of temperature (-3, 0, +3, +6, +9°C), rainfall (-25%, −10%, 0, +10%, +25%), CO_2 concentrations (360, 450, 540, 630, 720 ppm) and nitrogen input rates (0, +25%, +50%, +100%, +150%).

Keywords: AgMIP-Canola, Crop simulation model, Multi-model ensemble, Sowing dates, Nitrogen inputs, Climate variability.

1 BACKGROUND: Crop modelling has been recognized as an efficient means to quantify climate change impact on crop production (Asseng et al., 2016; Franke et al., 2020). To gain confidence for using crop models to quantify yield potential, identify yield constraints and gaps, and identify ways to close the yield gaps, the Agricultural Model Inter-comparison and Improvement Project (AgMIP) has enabled the comparison of crop models with global datasets for the major crops and used multiple crop models for a given crop to quantify the uncertainty in simulations (Boote et al., 2015; Rosenzweig et al., 2014).

The original purpose of the dataset was to better understand how climate change might influence global canola production (Wang et al., 2022). We completed the first inter-comparison of eight crop models for simulating growth and seed yield of canola, based on experimental data from six sites across five countries, covering a wide range of environments. We further conducted sensitivity analysis with a full factorial combination of five levels of atmospheric CO_2 concentrations, seven temperature changes, five precipitation changes, together with five nitrogen application rates. The work involved 20 scientists in six countries, working together within the AgMIP-Canola project Phase I (https://agmip.org/canola/). The key results have been published in a research paper (Wang et al., 2022). Here we publish the experimental dataset and the detailed simulation results generated in the project.

2 FIELD EXPERIMENTS: The field experimental data were collected from six sites across five countries: Young (34.4°S, 148.3°E, New South Wales) (Kirkegaard et al., 2012) and Hamilton (37.8°S, 142.1°E, Victoria) (Christy et al., 2013) in Australia, Wuchuan (31.5°N, 104.6°E, Inner Mongolia) in China, Rosdorf (51.2°N, 9.5°E, Göttingen) in Germany, Ottava (40.7°N, 8.3°E, Sassari) in Italy and Ames (42.0°N, 93.7°W, Iowa) in USA. There were seven canola cultivars used in the experiments, including four spring cultivars (46Y78, Hyola50, Big Yellow and Oasis) and three winter cultivars (Taurus, Visby and Kabel). The experiment at each site consisted of treatments with different sowing dates (Young, Wuchuan, and Ottava), different years of sowing (Hamilton and Ames), or different nitrogen application rates (Rosdorf). Initial soil water, soil carbon and nitrogen measurements were available for all the sites, which were used to initialize the soil variables in the crop models. Canola phenology (sowing dates, flowering dates and maturity dates), LAI, final biomass and seed yield were measured in all the experiments. Organ biomass, nitrogen uptake, nitrogen in seed, and seed oil were available for some sites. Table 1 shows the details of treatments and measurements.

3 SIMULATION OF FIELD EXPERIMENTS AND SENSITIVITY ANALYSIS: Ten individual model frameworks, including eight crop models, i.e., APSIM, CAT-Canola, DSSAT, DayCent, DNDC, HUME, MONICA and SIMPLACE, were used to simulate all the field experiments. Two different versions of APSIM (APSIM 7.6 and APSIM 7.7) were used by two groups of modellers, while the same version of DSSAT 4.6 was used by two different modelling groups. Those models are the registered models under the AgMIP-Canola Initiative Phase I (https://agmip.org/canola/). A two-step calibration approach was used to calibrate individual models against the experimental data. Step1, called Partial calibration, used only observed flowering and maturity dates from one treatment at each site to calibrate cultivar parameters for phenology modelling. Step 2, called Full calibration, used all the information (including final biomass, seed yield, LAI, seed oil content, in-season biomass, In-season LAI, water and nitrogen uptake, soil water and nitrogen dynamics (if available) from the given treatment to further calibrate the models. Here we supply the simulation results of ten individual model frameworks for all the treatments after the full calibration.

After full calibration, nine modelling groups conducted a full multi-factorial (temperature × rainfall × atmospheric CO_2 concentration × N rates) combination of simulations (Table 2) with 30 years of historical daily weather data (1981-2010). The representative cultivar, sowing date, starting condition and reference N application rate were given in Table 1 (sensitivity analysis section). In total, 625 simulations (5×5×5×5) were conducted at daily time step for each site. Soil conditions including soil water, N content and surface organic matter at sowing were reset annually to the values shown in Table 1. Only yearly outputs from the models were required to compare the response differences between the models.

Table 1: Site information, canola cultivars, treatments, key soil and management information of the field experiments and representative cultivar, sowing date, N input and starting conditions used in the sensitivity analysis

Experimental site	Young	Hamilton	Wuchuan	Rosdorf	Ottava	Ames
Country	Australia	Australia	China	Germany	Italy	USA
Site abbreviation	AUYG	AUHA	CNWC	DERD	ITOT	USAM
<u>Experiments</u>						
Cultivar	46Y78[s]	Hyola50[s] Taurus[w]	Big Yellow[s]	Visby[w]	Kabel[w]	Oasis[s]
Treatments	***<u>S1</u>***, S2, S3	***<u>Y10</u>***, Y11, Y12	S1, S2, ***<u>S3</u>***, S4, S5	N0, N1, ***<u>N2</u>***	***<u>S1</u>,*** S2, S3	***<u>Y13</u>***, Y14
Sowing dates (dd/mm/yyyy)	S1: 17/04/2008 S2: 30/04/2008 S3: 12/05/2008	Y10: 30/04/2010 Y11: 29/04/2011 Y12: 18/05/2012	S1: 26/04/2012 S2: 6/05/2012 S3: 16/05/2012 S4: 26/05/2012 S5: 31/05/2012	N0: 24/08/2012 N1: 24/08/2012 N2: 24/08/2012	S1: 9/11/2009 S2: 20/11/2009 S3: 12/12/2009	Y13: 6/04/2013 Y14: 18/04/2014
Total nitrogen input (kg N/ha)	S1: 72 S2: 72 S3: 72	Y10: 110 Y11: 97 Y12: 45	S1: 30 S2: 30 S3: 30 S4: 30 S5: 30	N0: 0 N1: 100 N2: 200	S1: 128 S2: 128 S3: 128	Y13: 135.52 Y14: 135.52
Soil PAWC* (mm)	160	194	248	190	88	249
<u>Measurements</u>						
Initial soil water	Yes	Yes	Yes	Yes	Yes	Yes
Initial soil C, N	Yes	Yes	Yes	Yes	Yes	Yes
Phenology	Yes	Yes	Yes	Yes	Yes	Yes
LAI	Yes	Yes	Yes	Yes	Yes	Yes
Biomass (organs)**	Yes(Yes)	Yes(Yes)	Yes(Yes)	Yes(No)	Yes(Yes)	Yes(Yes)
N uptake	No	No	Yes	Yes	Yes	No
N in seed	No	No	No	Yes	Yes	No
Seed yield	Yes	Yes	Yes	Yes	Yes	Yes
Seed oil	Yes	Yes	No	No	Yes	Yes
<u>Sensitivity analysis</u>						
Cultivar	46Y78	Taurus	Bigyellow	Visby	Kabel	Oasis
Sowing date	1-May	1-May	16-May	30-Aug	9-Nov	12-Apr
N input (kg/ha)	100	100	75	180	128	112
Initial SW* (%)**	80	80	60	50	100	100
Initial N (kg/ha)	112	538	138	71	19	41

[s] and [w] represent spring and winter cultivars, respectively. *Si, Ni, Yi* represents different sowing date, nitrogen application rate, sowing year treatments, respectively. Treatment names in underlined bold and italic indicate data used for model calibration. The rest of the data were used for model validation. *PAWC is the maximum amount of water that the soil can hold for crops to use, i.e. plant available water holding capacity. No irrigation was applied in any of the experiments. **The Yes/No in brackets indicate the availability of the organ biomass. ***Initial soil water is the fraction of PAWC.

Table 2: The factors changed in the sensitivity analysis

Temperature*	−3, 0, +3, +6, & +9 °C offset from current
Rainfall Amount	−25, −10, 0, +10, +25% of current
CO_2 levels	ambient (360 ppm), 450, 540, 630, 720 ppm
N fertilizer	N increments in 0, 25, 50, 100, 150% of reference N application

* Maximum and minimum temperature changed together

4 DATA FORMAT, STRUCTURE AND AVAILABILITY: Table 3 gives an overview of the structure and content of the dataset. There are three folders in the dataset including *experimental_observation*, *model_simulation* and *sensitivity_analysis*. Experimental and simulation (model output) data are provided in excel files or space-delimited txt files.

Table 3: Overview of the organisation of the dataset.

Folder name	File name	Content
Experimental_observation	AUHA_Hyola50_Observation.xlsx AUHA_Taurus_Observation.xlsx AUYG_46Y78_Observation.xlsx CNWC_BigYellow_Observation.xlsx DERD_Visby_Observation.xlsx ITOT_Kabel_Observation.xlsx USAM_Oasis_Observation.xlsx	Each excel file named "location_cultivar_observation.xlsx" contains site&management information, soil water and mineral nitrogen measurements, crop measurements and daily weather data during the experimental period
Model_simulation	APSIM76_Simulation.xlsx APSIM77_Simulation.xlsx CAT_Simulation.xlsx DayCent_Simulation.xlsx DNDC_Simulation.xlsx DSSAT_Group1_Simulation.xlsx DSSAT_Group2_Simulation.xlsx HUME_Simulation.xlsx MONICA_Simulation.xlsx SIMPLACE_Simulation.xlsx	Each excel file named "model_simulation.xlsx" contains the daily step simulation results for the experimental period. The model outputs include model, cultivar, treatment, year, day of year, stage, LAI, PAI, biomass (Biom), grain yield (Grain), root biomass (Root), N in biomass (BmN), N in grain (GrnN), N in root (RootN), seed oil content (GrnOil), soil water evaporation (Evap), plant transpiration (Transp), runoff, drainage (Drain) and the modeller.
Sensitivity_analysis	AUHA _SensitivityAnalysis.txt AUYG _SensitivityAnalysis.txt ITOT _SensitivityAnalysis.txt DERD _SensitivityAnalysis.txt USAM _SensitivityAnalysis.txt CNWC _SensitivityAnalysis.txt	Each txt file named "locationl_SensitivityAnalysis.txt" contains the annual step simulation results for the sensitivity analysis from nine modelling groups. Each file contains the model name (Mod), Cultivar, factors (Temperature (T), Rainfall (R), CO_2 concentration (C), N rates (N)), Year, Anthesis date, harvesting date, Maximum LAI (Max_LAI), final biomass (Biom), final yield (Grain), root biomass (Root), N in the biomass (BiomN), N in the seed (GrnN), N in the root (RootN), total evaporation (Evap), total transpiration (Transp), total runoff (Runoff), total drainage (Drain).

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